ENGINEERING HELIOGRAPHY, OR THE SUN-PRINT COPYING OF ENGINEERING DRAWINGS.

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Introduction.

Since the appearance of the author's contribution to the *Minutes of Proceedings* of the Institution of Civil Engineers, entitled, "Heliography, or the Actinic Copying of Engineering Drawings,"* published some nine years ago, this rapid, accurate, and scientific method of reproducing engineering and architectural delineations has become exceedingly popular, and there are very few first-class engineers' drawing offices without some form of heliographic equipment. When this first paper was read, the number of engineering ateliers in which heliographic methods were utilized was exceedingly limited.

Engineers readily acknowledge that this scientific expedient has been of great advantage to them, both on the score of cost of production, and on the more important one of absolute fidelity of reproduction. The characteristics of the heliographic process are so important that its rapid popularization is not at all surprising. Heliography, properly understood and practised, enables the reproduction of dimensioned, mechanical, geometrical, or freehand-drawing delineations to be made with absolute fidelity to the original. Heliography, under favourable sunlight or actinic conditions (actinicism meaning the chemically acting energy of direct or diffused sunlight), enables the most elaborate and detailed drawing to be reproduced in a small fraction of the time that would be absorbed in mechanically re-copying the original delineation.

Heliography permits the reproduction of an almost unlimited number of copies; it also enables by mere manipulation the production of a full-size elevation, plan, or section, from a half-drawn tracing, whenever such half-section is equal and alike in all particulars to the full section when drawn in duplicate. If the original or traced figure to be produced is figured partly on one side and partly on the other, or on the face of the tracing, this imperfection is not observable in the heliographic copy.

* Vol. lxxxvi., 1885, page 312.

Heliography possesses other advantages that may be appreciated from a commercial side, for instance the facility with which manufacturers and merchants can obtain copies of tracings lent to them for the preparation of estimates; this rapidity of the heliographic system has permitted manufacturers and merchants to tender or submit prices, at extremely short notice, who, probably, would not, but for this facile process, have had the opportunity of doing so.

Large drawings can also be built up of sheets reproduced by the heliographic process in a most satisfactory manner.

Drawing Office General Procedure.

The Preparation of the Original Tracing.—The following procedure is possible, as a consequence of the adoption of the heliographic copying method.

Instead of completing original drawings by inking them in, accurate tracings can be made, to serve as the office negatives; if alterations are made on the original drawings, new tracings can be made and marked and numbered, the original drawing being in pencil can be easily altered, whilst a comparison between the two tracings will immediately show the extent and character of the alterations, and the confusion often exhibited in an original drawing that has been altered, is thus avoided.

Besides, the new tracings would not show any obscurity or indefiniteness, and if marked consecutively and carefully dated, would show when the alteration was decided upon.

If the tracings are carefully preserved, they will form a record of the work as carried out. Each tracing should be accompanied by a heliograph (which should serve for use in the drawing office), in addition to the several duplicates required for the workshops. The tracing itself should be carefully kept, uncreased and unsoiled, for special reference, and for heliographic purposes.

The author does not intend to describe all the various heliographic formulæ, because a reference to his previous paper will enable the student to follow up the subject more exhaustively. The author will confine his remarks to a description of those processes that have won their way to popularity by the action of the law of the survival of the fittest.

Outline of Procedure.—The practical art of heliography or sun-drawing is simplicity itself. The procedure may be divided into three divisions. (*a*) The preparation of the original delineation or figure on translucent material, such as tracing-paper or tracing-cloth. (*b*) The application of a special and actinically-sensitive

paper to the face of the traced delineation to be reproduced. (*c*) The exposure of the delineation, with its accompanying actinically-sensitive paper to the effect of actinically active daylight, or in other words, to the effect more or less direct of solar light, or its near equivalent, such as an electric arc-light, of which the luminous rays have associated actinic or chemically active energy. It may here be stated that with electric arc-lights of 6,000 candle-power, both the Pellet (which requires half an hour) and the other cyanide papers can be actinically printed. (*d*) The removal of the sensitive paper, after adequate exposure to the influence of actinic or chemically active light, to the developing solution. (*e*) The application of the adequately exposed sensitive paper to the effect of the developing solution, for a sufficient time and in a proper manner, so as to leave on the surface of the sensitive paper, a distinct or well-defined, and more or less permanent, but absolutely accurate reproduction of the original delineation.

Outline Description of Heliographic Equipment.—To effect these five different processes peculiar to all methods of heliographic reproduction, an equipment of the following character is required:—(*a*) Tracing on translucent paper of a suitable character; (*b*) the actinically sensitive paper; (*c*) the printing-frame, by which the sensitive paper is exposed to the influence of actinic light; and (*d*) the developing-bath or baths by which the figure is permanently fixed.

Detailed Description of Heliographic Equipment and Agents.—A detailed description of the equipment as classified may now be given.

Tracing-papers.—The translucent character of the tracing-paper or cloth is of first importance. Strong yellow-tinted paper is not only unsuitable for rapid effect, but is inimical to accuracy of reproduction, because unless the rays of light falling on the plane of the glass of the printing-frame are directly at right angles to it, the thickness of the tracing paper tends to produce a distorted and indefinite image.

Special thin blueish-white, or almost white parchmented and alkaline papers, highly translucent, and only tearable by somewhat violent tension, are now manufactured, and are undoubtedly the ideal paper for heliographic use. The cost of such paper of thin alkaline quality, and for lengths of 66 feet by 30 inches wide, is 0·144d. per square foot, while a better quality costs 0·28d. per square foot.

After use, the tracings should, as far as possible, be preserved from sunlight, because by actinic and chemical action of light the paper is apt, not only to lose its transparency, but also to become brittle, and white, opaque creases and lines are the result of its being folded.

It is not advisable that the tracing should be folded, because the folds not only tend to destroy the translucency, but they make it more difficult to obtain a close contact between the tracing and the glazed surface (glass) of the printing-frame. The importance of a close contact although obvious, may be thus enunciated; wherever a tracing is in imperfect contact with the sensitized surface, the light-rays flow beneath the opaque lines of the drawing, and there is consequently no reproduction within the area of contact-imperfection.

If the tracings are required to be rolled, they should be wrapped around stiff cardboard or wooden rollers at least 1½ inches in diameter, and carefully stored in positions removed from actinically active light.

Translucent Drawings.—Ordinary drawing-paper can be made temporarily translucent by immersion in benzine, but in order to permit of its use for heliographic reproduction a rapidly sensitive character of paper must be employed. Special translucent parchment drawing-paper suitable for heliographic reproduction can now be obtained.

It is always advisable to cut the heliographic paper which is to be actinicized, of a size slightly larger than the tracing, so that its margin protrudes from under such tracing ; the effect of the actinic light on the exposed paper will be a measure of that under the tracing, being, of course, slightly less under the tracing, and in a degree depending upon the translucence of the latter.

The Printing-frame.—This part of the heliographic equipment permits of the sensitive paper being placed in contact with the figured tracing, under the influence of actinic light.

The degree of success in the process of heliography greatly depends upon the merits of the printing-frame. The apparatus should possess the following qualifications :—

It should permit the operator to place the figured tracing rapidly in position, and in close and equal contact, effected by well distributed pressure applied over the entire surface of the tracing. If the pressure by which the tracing and sensitized paper are brought together, is local in its effect, irregularities and false impressions are produced, besides which the wrinkles and creases produce shadows on the heliograph copy.

It is advisable to employ at least two sizes of printing-frames, one of which shall be large enough to permit the exposure of double elephant copies, 30 by 43 inches, the other and smaller are to be sufficient for taking royal copies, 19 by 26 inches.

When larger copies than the frame can take are required, a line in pencil should be drawn across the tracing so that the heliograph can be

copied in sections, which are afterwards fastened together with gum or any other suitable translucent medium, at the line of connexion. The author has obtained excellent and very large copies in this way.

The structural characteristics of the printing-frame itself are simple enough, and will be understood from the drawings of different types submitted, and from the actual examples exhibited.

The glass of good plate quality, free from blows, streaks, and all blemishes, either of inequality of thickness or of translucency, should be at least, for the double elephant size, $\frac{1}{4}$ inch in thickness, while for the smaller frame $\frac{3}{16}$ inch plate-glass may be employed.

In order to equalize the pressure of the backboard on the surface of the tracing and sensitized paper, thick, soft felt, at least $\frac{3}{8}$ inch thick, or a piece of trebly-folded flannel, will satisfy requirements. Indiarubber sheets, the full size of, and attached to the edges of the felt or flannel, will improve the equalizing action of the felt.

The edge-frame should be as strongly proportioned as convenience of portability will permit, and be rebated so as to carry the plate-glass and the considerable pressure brought to bear upon its surface.

The backboard of well-seasoned wood, if not in separate parts, should be stiffly constructed and well bound up. It should have two handles to facilitate handling. If the backboard is in separate battens, the centre batten should be the first to be applied—each batten to have its clamping-down springs. There are several methods of clamping-down the backboard to the felt. The pressure is principally applied by steel springs, either flat, helical, or coil.

In the Street printing-frames, an air-cushion is attached to the frame, and by mouth-blowing both an equable and a considerable pressure can be produced.

The author's method of mounting the printing-frame is shown in Figs. 1 and 2 (Plate III.). This arrangement enables the frame to be swung round at any angle, and to be reversed when placing the tracing and sensitized copy in the printing-frame.

The glazed frame is also available, and is not uncommonly used in the author's drawing office for tracing direct on to parchment or drawing-paper. A powerful light is placed beneath the inclined glazed surface, on the other side of which is the figured paper. The light passing through the glass and drawing enables the draughtsman to trace the figure on to the drawing or parchment-paper direct.

Methods of Exposing Printing-frame to the Influence of Actinically Active Light.—The printing-frame is mounted on special bearings, and is

easily moved about. The details of these bearings are shown in Figs. 3 and 4 (Plate III.).

When rapid effect is desired, and when circumstances admit, the Allott and Jones arrangements shown in Figs. 5 and 6 (Plate III.) can be adopted. Another arrangement for bringing the frame into proper exposure or so as to get the direct rays from the zenith, where only attic lights are available, is shown in Fig. 7 (Plate III.). The frame is hoisted up to the inclined glazed part of the roof or fan-light, counter-balancing arrangements being adopted to facilitate the raising of the frame to the desired position.

When at all convenient, the arrangements shown, or any others that permit of exposure in the open air, are undoubtedly the best. Glazed windows absorb much of the actinic energy of sunlight. The ideal position is to so incline the frame that it may face the sunlight at right angles, in order to obtain the direct rays from the zenith. When direct light cannot be obtained, recourse can be made to the Hayward or other forms of street-area reflecting-mirrors. Fig. 8 (Plate III.) shows the Thwaite printing-frame associated with reflecting-mirrors.

Of course it is not absolutely essential to expose the printing-frame in the open air. The author has obtained hundreds of copies with the printing-frame placed inside the office.

When electric arc-lights are employed, the printing-frames may be placed in a circle around the light, some 6 feet distant from it. The best arrangement for applying the arc electric-light for actinic printing is that adopted by Mr. W. H. Stanley, London, and is diagrammatically shown in Fig. 9 (Plate III.). Three printing-frames are arranged within a distance of 2 to 3 feet from an arc-lamp, and in order to obtain an equal light-diffusion, condenser-lenses are suspended from the casing of the arc-lamp. The current used has a pressure of 50 volts, and the quantity of energy is equivalent to 50 ampères. With an arc-light of this intensity satisfactory ferro-gallic (black and white) copies are obtained, with an exposure of about 3 hours. The necessary arc-light exposure when using ferro-prussiate papers is less, not more than $2\frac{1}{2}$ hours being required to obtain satisfactory prints.

On Placing the Tracing in the Printing-frame.—The *modus operandi* is simply as follows:—The figured tracing to be copied is placed with its figured surface next to the glass of the printing-frame. The sensitized paper, with its actinically sensitive or prepared surface next to the tracing is carefully and uniformly pressed into contact with it. The felt is now laid carefully upon the paper, and in such a way as not to disturb the

position of either the tracing or the sensitive paper. The backboard is then placed on to the felt, the clamping-bars are fixed in place, and gradually screwed, or, by means of springs, pressed down, so that the two papers are uniformly pressed against each other, creases or crumples not being permitted.

No obstacle, such as a mullion or sash of a window, should be allowed to intervene between the (actinic) light and the printing-frame. The shadow of such an obstruction would distinctly mar the heliograph copy produced.

Cutting and Placing the Sensitized Paper.—With the ordinary ferro-prussiate process paper in which the figure is delineated in white-lines on a blue-ground no special anti-actinic precautions in cutting the sensitive paper and placing it into the frame need be observed. If the paper is rapidly removed from its case, and cut with its face on the glass of the printing-frame (sensitive face downwards) it will not be affected by the momentary exposure to the diffused light of the office.

With very sensitive papers it is advisable to remove them from their case and apply them to the printing-frame in non-actinic light. The author has for many years used ordinary yellow window-blinds with success; but if a permanent non-actinic effect is desired the windows should be glazed with ruby or amber-coloured glass, or be covered with yellow or amber-coloured "glacial" papers.

The Direct Procedure for Producing Different Heliographic Effects.

The various chemical formula for producing the different sensitizing surfaces are given in the Appendix. It may, however, be said that the different sensitized papers are produced so cheaply by manufacturers making a speciality of this class of paper that there is little, if any, economy in the individual preparation, and especially is this so with the Shawcross ferro-gallic paper. This paper can only be produced by special machinery, and as an example of the manner of approaching this subject by two industrial nations, it is a fact that this paper is being principally made in Germany. The inventor was not able to find a British manufacturer willing to provide the proper machinery, and abandoned his patent rights.

Outline of Various Processes in More or Less Regular Use.—The different processes may be taken in the following sequence:—(1) The production of a white-line reproduction on a dark prussian-blue ground by the ferro-prussiate process; (2) a dark prussian-blue line reproduc-

tion on a white-ground, the ferro-cyanide or Pellet process; (3) an ink-black line reproduction on a white-ground, the ferro-gallic or Shaw-cross process; (4) a black-line reproduction on a white-ground, the melagraphic, a private, process; and (5) a white-line reproduction on a black-ground, the platinotype process.

Suggested Specification for Sensitive Papers.—In ordering actinically-sensitive papers, the following are the necessary requirements:—(*a*) To be of a high degree of sensitiveness; (*b*) to have excellent keeping qualities under proper conditions of storage and climate; (*c*) guaranteed permanence of the heliographic reproduction; (*d*) to be workable in any weather; and (*e*) to be easy of manipulation.

Specimens of various heliographic processes are shown in Plate IV., Figs. 13, 14, 15, and 17 being printed by Messrs. Allott and Jones, of Liverpool, and Fig. 16 by Mr. J. R. Gotz, of London.

(1) *White-lines on Blue-ground (Ferro-prussiate) Process.*

Quality of Paper.—A satisfactory quality of paper should not, when folded, exhibit white creases at the folds. Ferro-prussiate prepared cloth must be preserved from the light, and even be cut in non-actinic light.

Cost.—Workshop paper, good and strong, 32 feet by 40 inches, costs 0·577d. per square foot. Extra thin, for foreign postage and for producing second and positive copies, 32 feet by 40 inches, costs 0·975d. per square foot. Ferro-prussiate calico, 32 feet by 30 inches, costs 1·278d. per square foot. Extra-rapid effect, or extra-sensitive paper is 30 per cent. more costly than the slower and less sensitive papers.

Exposure.—The length of exposure in the printing-frame depends, of course, upon the sensitiveness of the paper, the average times being :—

	For super-sensitive rapid papers.		For slow or only moderately sensitive papers.
In bright sunshine...	3 to 7 minutes.	...	15 to 20 minutes.
In diffused daylight,			
fair weather ...	5 to 10 „	...	20 to 30 „
dull weather ...	15 to 30 „	...	1½ hours to 2 hours.

With rapid or super-sensitive paper, special care should be taken in watching the exposure; the lines of the figure on the completion of the exposure should appear in a light tint, whereas with the slow-acting paper the lines should appear of a bluish-black colour.

Colour-changes.—The colour-changes under exposure to actinic light influences are :—

1st	colour-period,	before exposure,	yellow.
2nd	„	after „	greenish-yellow.
3rd	„	„ „	greenish-grey.
4th	„	„ „	bluish-grey.
5th	„	complete exposure,	olive-blue colour with metallic reflections.

The more powerful the actinicism of the light, the darker the olive-blue colour resulting from the complete action.

Development.—The completely-exposed sensitized paper should be removed from the printing-frame and be vertically immersed in water in the Thwaite vertical-bath, in the manner shown in Fig. 10 (Plate III.), or if the horizontal type of bath be used, the water should be applied with a rose, allowing the effluent flow from the prints to be continuous. The sensitized surface that has been preserved from the actinic light is washed off, leaving the figure in pure white lines. The print is then removed to dry, being hung by the side of the vertical bath or from a cord-line. By the use of blotting-paper the action of drying may be accelerated.

By employing water heated to 90 degs. Fahr. in the bath the development is more rapid and more complete. Evidence of under-exposure is shown after washing by the paleness of the blue-ground, and of over-exposure by the imperfectly white and tinted blue-lines.

By a simple adaptation of the ferro-prussiate procedure blue-line figures on a white ground can be obtained.

Ferro-prussiate Blue-lines on White-ground Procedure.—A specially thin kind of sensitized paper is used to obtain a negative or white-lines on blue-ground copy. This thin paper is similar to that employed for foreign postal purposes, and can be obtained in lengths of 32 feet at the price of 1·33d. per square foot.

This negative heliograph copy is then, and instead of the tracing, placed in the printing-frame, and another piece of sensitized paper is placed with its sensitive surface in contact with the figured side of the negative, or in the contrary position to that adopted in the tracing procedure, in which the figured tracing is placed next to the surface of the glass of the printing-frame. The time of exposure is, under identical conditions of actinic influence, four times greater than is required in the first or negative procedure.

In washing the ferro-prussiate prints, where the Thwaite vertical-bath is not available, an ordinary indiarubber tube should be provided, so that the water may be delivered over the entire surface of the paper; if the pressure be strong enough the use of a brush will not be required. The improper use of a brush will destroy the integrity of the lines.

(2) *Blue-lines on White-ground (Ferro-cyanide or Pellet) Process.*

Paper.—Mounted or unmounted paper can be obtained.

Cost.—Calico-mounted paper in 32 feet lengths, 30 inches wide, costs 2·30d. per square foot. Stout paper in 32 feet lengths, 30 inches wide, costs 1·05d. per square foot, and 40 inches wide, costs 1·015d. per square foot.

Exposure.—In the highly actinic sunlight of springtime, 20 seconds ; dull or indirect light, 2 to 3 minutes ; winter light, 5 to 30 minutes.

The exposure should be checked as follows :—Take six slips of the sensitized paper, each slip is then to be placed behind tracing-paper slips, on which lines as delicate as those on the tracing have been marked, and on an identical character of tracing-paper. The slips are then placed in a small printing-frame with a backboard, having as many hinged partitions as there are slips, and exposed to the same conditions of light as in the large printing-frame. During the exposure, the slips can be examined to test the position of the colour-changes.

Development.—Pellet sensitized paper, on removal from the frame, may be kept for several days, if it is not convenient or desirable, on account of absence of actinic light, to effect immediate development.

The exposed paper should be transferred to a saturated solution of ferro-cyanide of potassium (3 ounces of yellow prussiate to each quart of water). This solution should be contained in a guttapercha-lined tray. The exposed paper should not be immersed in the developing-solution in such a way that the solution reaches the back, but floated with its sensitive surface in contact with the solution. This may be easily done by turning up the edges of the exposed paper, which we will in future refer to as the heliograph or print. The print should be exposed to the solution for 40 seconds.

After the completion of the development, the print should be floated face downwards upon clean water in an acid bath composed of 8 parts of hydrochloric acid and 3 parts of sulphuric acid to 100 parts of pure water, say 3·6 ounces of hydrochloric acid and 1·2 ounces of sulphuric acid to each quart of water ; an alternate formula being 5 ounces of sulphuric acid to one gallon of water. The acids should be mixed together in an earthenware vessel, and be poured into a second tray and guttapercha-lined bath. From 6 to 8 minutes is adequate to allow for the acid reaction on the iron compounds, and for the removal of the redundant iron compounds by the acid solution.

If the fingers are stained in the developing process, the colour can be removed by washing them in a diluted alkaline solution of caustic soda

or potash. In order to prevent the staining of the hands or discolouration of the prints during manipulation, it is a good plan to wear white cotton gloves.

In order to ensure uniform contact with the solution a camel's hair brush should be carefully pressed over the back of the heliograph print, so as to expel the air-bubbles.

If the ground of the Pellet copies is not quite free from blue discolouration, it may be effectually bleached in the summer months by being exposed to a 4 per cent. solution of sulphuric acid; in the winter months the solution may be strengthened up to 6 per cent. of sulphuric acid. Properly exposed, perfect development has been obtained if the lines appear in dark blue on the original yellow ground.

Although Mr. Shawcross has a just claim to be considered the pioneer of the ferro-gallic process, which will be described further on, he strongly recommends the Pellet procedure and formulæ. He has made use of this process for many years, but he adopts a slight deviation in the developing process.

Pellet copies, properly washed and mounted, make admirable drawings, and this process was extensively used by the late Count de Lesseps in his engineering ateliers. They leave nothing to be desired on the score of permanency, as the examples of Lesseps' drawings shown by the author proved.

Special Method of Development.—Mr. Shawcross' modified method of developing will be understood by reference to Fig. 11 (Plate III.). A drawing or other plane board, *a*, of suitable size is inclined slightly from the vertical against the uprights *b*, which may be placed against a wall *c*. The exposed sensitized paper or print is pinned on to the board with its sensitive side on the upper surface. An enamelled metal and spouted vessel, *d*, is used for containing the solution of ferro-cyanide of potassium (yellow prussiate) in the proportions already described. The solution may be heated, and is poured over the surface of the paper in all parts, and the development takes place forthwith. The solution flows to the lower end of the board, where it is caught by the trough *e*, which is inclined towards an escape-pipe or tube *f*, into which it flows, and descends to the brown earthenware vessel *g*, provided with a cover *h*, so as to prevent the incursion of dirt or liquids. The vessel, *g*, should always be maintained full of a saturated solution of ferro-cyanide (yellow prussiate of potash) of which crystals are shown at *i*.

The advantages of this method of development may be summarized as follows:—(*a*) The developing process is visible; (*b*) the developing solu-

tion can be heated to a temperature appropriate for the season of the year; (*c*) less space is occupied; and (*d*) the cleanliness of the developer and the recovery of the used solution.

If the lines of the print during development have a tendency to spread, it is evident that the developing solution is a little too strong, or that the exposure has been inadequate. If the lines are imperfect in continuity, that is evidence of over-exposure.

Final Washing.—After the print has been exposed to the acid solution, it should be thoroughly washed, as described, for the ferro-prussiate process.

For making alterations in copies made by the Pellet process, a solution known as blue-solving is sold by manufacturers.

The acid bath may occasionally be cleansed with a potash dissolving solution.

(3) *Black-lines on White-ground (Ferro-gallic) Process.*

Since the author first introduced this process (invented by Mr. Shawcross) great improvements have been effected in its manufacture, and although the formulæ are given in the Appendix, nevertheless, except for research purposes, the author does not advise individual attempts to make this paper. Thanks to the intelligence of German manufacturers, satisfactory ferro-gallic paper can now be obtained from English stationers.

Paper.—It is a good precaution, the night before the paper is required to be used, to uncoil such part of the roll of paper as will be cut, as a better, denser, and stronger colour-tone will then result.

Cost.—Thin quality of paper in 32 feet lengths, 30 inches wide, costs 1·05d. per square foot; medium quality costs 1·05d. per square foot; thick quality costs 1·27d. per square foot; and mounted on calico, it costs 2·7d. per square foot.

Time of Exposure.—The colour-changes are: First period, before exposure, yellow; second period, after exposure, fainter yellow; third period, after exposure, still fainter yellow; fourth period, after exposure, white ground. The tint disappears, leaving the figure or delineation in the original yellow tint.

The exposed paper or prints may be stored in cases for subsequent development for as long a period as ten hours. If the exposure is not completed by the time the colour has set, it may be allowed to remain in the frame until the following morning, when the exposure can be extended to completion.

Development.—It is advisable, although not necessary, to submit the surface of the print to water-contact before exposing it to the developing influence, and this prior water-contact influence increases the density of the lines.

The developing-solution is composed of 40 grains of gallic acid per 1 pint of water. It should be stored in a guttapercha-lined bath. Another developing proportion is $\frac{3}{4}$ ounce of gallic acid (mixed in earthenware vessels) per 1 gallon of water. The solution can be employed several times. The solution will be serviceable for a longer period, if the development be deferred until some hours after the removal of the print from the printing-frame.

Immediately the print is placed in the solution (if tepid, so much the better) the yellow lines will become a very dark violet-black. It is also desirable to subject the printed surface after development in the gallic acid solution, to contact with clear water for five minutes, or until the print has no colouring influence on the water.

If the print after development is not quite white, but violet tinted, it is evidence of under-exposure, whereas if the lines are not black the print has been over-exposed. The prints can be hung to be air-dried. Ferro-gallic prints can be treated exactly as if they were drawings.

(4) *Black-lines on White-ground, Melagraphic Paper (the Marion Process).*

Paper.—This paper is probably based on the ferro-gallic process, but only requires pure-water development.

Various qualities of paper are produced, including a linen-mounted one.

Cost.—The paper, in 32 feet lengths, 30 inches wide, costs 1·50d. per square foot, and 40 inches wide, costs 1·52d. per square foot.

Exposure.—The exposure is similar to that described for the ferro-gallic procedure.

Development.—The face of the print should be carefully brought into close and complete contact with the developing-solution, which, for this paper, is pure water. The contact should be effected without disturbing the water, otherwise the lines of the figure will appear to be broken. The heliograph print should be left undisturbed in the water for half a minute. The print may then be brushed over with a soft camel-hair brush and hung up to dry. The water, after a minute's contact with the heliograph print, will become highly discoloured.

The print should be removed from this bath to another, in which a steady flow of water from an indiarubber tube is directed over the surface of the print.

Drying.—It is best to allow the print to dry, by being hung up and exposed to simple air-evaporation.

(5) *White-lines on a Black-ground, the Platinotype (Willis) Process.*

This process is only recommended for reproducing small drawings. It gives most exquisite and permanent reproductions, and it is also very sensitive.

Cost.—The cost of the paper, except for special application, precludes this beautiful process from being generally used. The price per 24 sheets, each 20 by 16 inches, may be reckoned at 1s. per square foot.

Exposure.—The entire process with this paper must be carried on in obscure and non-actinic light. A few minutes' exposure to ordinary daylight is adequate, and should be carefully watched.

The colour-changes are as follows:—First period, before exposure, yellow; second period, after exposure, pale greyish-brown; third period, after exposure, dull-orange hue. The last colour-change shows that the iron compounds have been reduced.

Platinotype prints need not be immediately developed, but they should be preserved from moisture by being placed in cases, in which there is a lid containing calcium chloride.

Development.—The surface of the print should be placed for at least four seconds in a solution composed of 130 grains of potassium oxalate to 1 ounce of water. The development will be instant and complete.

The print should then be washed for ten minutes in a solution composed of 10 parts of citric acid to 100 parts of water. Another, and perhaps better, solution is 1 part of hydrochloric acid to 60 parts of water.

The prints should be finally washed in copious relays of clean water for at least fifteen minutes.

Further Details of Procedure.

The Opacity of the Lines of the Delineation.—In the preparation of the tracing intended for heliographic reproduction, the first essential is the character of the lines of the figure, which should be of a high degree of opacity. The best liquid Indian ink should be employed, if prepared from the solid. Great care should be taken to make it sufficiently dense. Grey lines of imperfect opacity only give very imperfectly defined copies. The

opacity of the Indian ink can be increased by the addition of gamboge or chrome yellow, and the addition of raw sienna is highly recommended. A specially opaque Indian ink is sold by engineering stationers.

Shading.—Shading can be effected either by Indian-ink lines of varying breadth and distance, or by employing ink of variable opacity. The method employed in the author's drawing-office, and introduced by Mr. Vickers, is to shade with crayon and stump, by which most effective and pleasing results may be obtained. Lead-pencil shading may also be adopted, but not with such effective results as with the stump.

Colouring Negative Heliographs.—If variable coloured heliographs (white-figures on blue-ground) are desired, this can be effected, but with only partial success, and by employing a colour of high opacity for the tracing. This colour should be mixed with flake or Chinese white added in the necessary proportions to secure opacity. Instead of dead colouring, hatching in the different colours with the brush is very effective.

The coloured surfaces will be reproduced in more or less white tones on the heliograph, and on these surfaces the different colours, rendered opaque as described, can be applied.

Centre and Radial Lines.—Centre, radial, and dimension lines particularly for the ferro-prussiate process, are first drawn on the tracing with dotted Indian ink, or, if in full lines, with prussian blue, carmine, or raw sienna, to which is added a small portion of flake or Chinese white.

Characteristic Hatching.—A system employed on the Continent in use for negatives, or white-lines on blue-ground copies, as a substitute for structural materials classification, is the employment of characteristic hatching. The author has drawn up a suggested structural element classification code, shown in Fig. 12 (Plate III.). To avoid confusion, when employing characteristic hatching, a key or reference-table should be supplied.

Shrinkage of Heliograph and Tracing-paper.—In order to enable the exact shrinkage of important and complicated drawings, in which high delineative and scale-accuracy is important, it is advisable to draw on the tracing to be copied a scale in two directions at right angles to each other, and in exceptional instances in a diagonal direction as well. The shrinkage-scales will be reproduced in the heliograph copy, and will form an index of the shrinkage-action of the heliographic paper.

The shrinkage-degree depends, of course, on the texture of the paper, the denser and harder this is the less the shrinkage, while soft papers are subject to a much greater degree of shrinkage. The shrinkage of ferro-cyanide, ferro-prussiate, and Pellet papers is about 0·005.

Effecting Erasions and Additions to Cyanotype Heliographs.—For the ferro-prussiate copies, corrections and additions may be effected with a diluted solution of oxalic acid, or a solution of carbonate of potassium in the proportion of 1 part to 9 parts of water. Flake or Chinese-white colour may also be used.

For the Pellet process, a solution composed of 1 part of caustic potash to 28 parts of water is most effective for making alterations and erasures. The solution should be applied either with a quill pen or brush and be immediately blotted, to prevent the action from spreading. Oxalic acid may also be employed in the same proportion as the caustic potash.

A solution sold by heliographic stationers under the name of blue-solving enables additions to be made to heliographs produced by the Pellet process and in the same blue tint.

For the ferro-gallic process, a solution composed of 1 part of sulphuric acid to 99 parts of water, will enable erasures to be cleanly and neatly made.

Preparing the Heliographs for the Workshop.—When the ferro-cyanide or ferro-gallic heliographs are intended for the workshop they should be coated with hard white varnish. This will prevent the chemical character of the print from being damaged by stains from lubricating-oil, etc. For the rougher classes of work the prints should be mounted on linen, using fresh white paste (free from acid or alum) applied evenly to the back of the heliograph.

Excellent gummed paper on cotton for mounting heliographs, etc., can be obtained. The gummed surface should be damped with a sponge or soft brush, and the heliograph laid on and smoothed down from the centre with a soft cloth.

Excellent linen-mounted sensitized papers can now be obtained at such a price as to make their application more economic than the system of mounting ordinary-paper heliograph prints.

Tracing-Paper.—A good tracing-paper should possess the following qualifications. It should be extremely tough and be perfectly transparent. Alkaline papers are the best. It should not cockle or stretch with wash colour, nor deteriorate, either in translucency or toughness, with age. Tracing-cloth is an excellent medium for obtaining satisfactory heliographic prints.

APPENDIX A.—Sensitizing Solutions Applied to Paper.

(1) *Ferro-prussiate Process.*

The solution applied to the paper should be composed as follows :— Ferric ammonic-citrate, 140 grains ; potassic ferri-cyanide, 120 grains ; distilled water, 2 ounces. The solution should be kept in stoneware bottles, $9\frac{3}{8}$ ounces of ferric ammonic-citrate and $6\frac{1}{4}$ ounces of potassic ferri-cyanide being dissolved separately in pure water, and then made up to one quart of solution. The sensitizing solution should be applied to cream-laid paper, rolled and well sized by a flat damping-brush, 6 inches wide, or a tuft of cotton-waste, and the paper should be allowed to dry in the dark. The solution should be applied uniformly and just sufficiently to cover the paper. After drying in the dark the paper should be rolled and stored in special cases.

Theory of the Process.—The results are due to the influence of actinicism, as a reducing agent, on organic ferric salts, which are reduced to a ferrous state. Prussian blue is formed by the reaction of ferric compounds with potassic ferro-cyanide, while white ferrous compounds form a white soluble salt with the same liquid.

(2) *Ferro-cyanide or Pellet Process.*

The sensitizing solution is composed of the following constituents :— Sodium chloride, 3 parts ; ferric chloride, 8 parts ; hydrogen tartrate, 4 parts ; water, 100 parts.

The solution is thickened by the addition of 25 parts of gum arabic. In order to prevent the solution from sinking into the paper it should be applied as rapidly as possible. The theory is the same as that of the ferro-prussiate process.

(3) *Ferro-gallic or Shawcross Process.*

The sensitizing solution consists of :—Gelatine, 150 parts ; ferric sulphate, 60 parts ; sodium chloride, 94 parts ; hydrogen tartrate, 18·8 parts ; ferric chloride, 150 parts ; water, 110 parts.

The solution should be uniformly spread over the surface of unsized or specially treated paper, by means of a roller-pad, and the paper dried in the dark. It should then be dusted over with finely powdered gallic or tannic acid. The powder should then be thoroughly rubbed on to the paper, until it is brought into contact with every part of the sensitive surface, four coatings being applied. Some makers, in order to prevent

the sensitizing solution from approaching the size of the paper, pass the paper, before being sensitized, through very hot rollers, to harden the surface and prevent the sensitive solution from sinking into it.

Theory of the Process.—A ferric-gallate is formed by the combination of gallic acid with a ferric salt; this ferric salt, by the influence of actinicism, is reduced to the ferrous state.

(4) *Platinotype (Willis) Process.*

This process is patented, and the details of the sensitizing solutions are therefore not published. The theory of the process is based on the reducing action of a ferrous salt on metallic chlorides when exposed to actinic light.

APPENDIX B.—Specification of Heliographic Equipments.

(1) *White-lines on Blue-ground (Ferro-prussiate) Process.*

One printing-frame, either hung on standards on the Thwaite principle, or merely portable. The glass to be 41 inches by 28 inches, and $\frac{1}{4}$ inch plate, free from all blemishes. There should be a suitable size of felt pad.

The Thwaite vertical, or other ordinary horizontal or tray-bath should be lined with zinc and fitted with the necessary handles; and it should be of the dimensions suitable for developing the largest sized sheets that can be dealt with by the printing-frame. Cost about £5 10s.

(2) *Blue-lines on White-ground (Ferro-cyanide or Pellet) Process.*

Printing-frame and developing-bath as above.

One guttapercha-lined tray-bath of suitable dimensions.

One zinc-lined tray-bath, with handles, of suitable dimensions. Cost about £6 10s.

(3) *Black-lines on White-ground (Ferro-Gallic) Process.*

Printing-frame and developing-bath as above.

One lead-lined tray-bath and one zinc-lined tray-bath of suitable dimensions, and fitted with suitable handles. Cost about £8 10s.

The following gentlemen and firms, viz., Messrs. Bemrose & Sons, Limited, Derby; Eastman's Photographic Materials Co., Limited, London; Mr. J. R. Gotz, London; Mr. Richard Keene, Derby; Messrs. Marion & Co., London; Mr. Parry, C.E., Liverpool; Messrs. Smith & Co.,

Manchester; Mr. W. F. Stanley, London; and Messrs. Thwaite, Tozer, & Co., Limited, London; exhibited examples of heliography by the ferro-cyanide, the ferro-prussiate, the ferro-gallic, the platinotype, and the baryte processes. A fine and interesting collection of every-day examples of heliography, as carried on under the supervision of Mr. Shawcross, C.E., of the waterworks engineer's department of the city of Liverpool, were exhibited. This collection lent by Mr. Parry, waterworks engineer, Liverpool, proved the permanency of ferro-cyanide and ferro-prussiate prints, a qualification further proved by drawings from the late Count de Lessep's ateliers, and by other French and Spanish examples nearly twenty years old. Some of the tracings and heliographs exhibited were prepared by Mr. Shawcross seven years ago; and both tracings and heliographs were in an excellent state of preservation. A comparison of the tracings with the heliographs, some of which showed patches, proved the readiness with which erasures could be made, and imperfections could be remedied. A very large heliograph cartoon (180 inches long by 30 inches wide) showing the dam of the Vyrny waterworks, illustrated how a very large scale drawing can be made by first preparing the details to one large scale (none of the drawings being larger than double-elephant or drawing-board size), then taking multiple copies and combining them up into a compact whole. The heliograph cartoon showed a long elevation to a large scale made up in this way in a most rapid and convenient manner, the only parts drawn in by hand being the varying rock-surface of the ground. The mounted heliographs shown appeared to be permanent and as effective as ordinary drawings. Other copies illustrated the original experiments made by Mr. Shawcross in converting the Pellet or ferro-cyanide (blue-line) process, into darker blue or black-lines. Other interesting exhibits showed the development of the ferro-gallic (black-lines on white-ground) process, of which Mr. Shawcross was the original inventor; the high state of perfection of this process was shown by numerous examples from well-known firms. Examples of a black-line on white-ground process, with merely a water-developer, were shown by several of the exhibtors, together with a series of platinotype prints by Mr. Richard Keene, of Derby. Examples of suitable tracing papers, printing frames, and other requirements of a heliographic equipment were exhibited. Eastman's Photographic Materials Co., Limited, exhibited examples of baryte paper. The methods of shading, colouring, and characteristic methods of colouring constructional drawings that have to be heliographed were shown by several exhibits prepared by Mr. Vickers of Messrs. Thwaite, Tozer, & Co., Limited.

This exhibition was the first of its kind, and should tend to the popularization of engineering heliography as an aid to engineering construction.

The PRESIDENT moved that a vote of thanks be given to Mr. Thwaite for his valuable paper.

To illustrate Mr. B.H. Thwaite's Paper on "Engineering Heliography" etc.

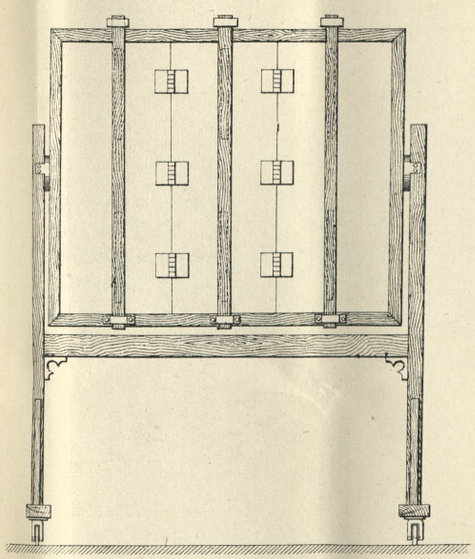


FIG. 1.—BACK ELEVATION.

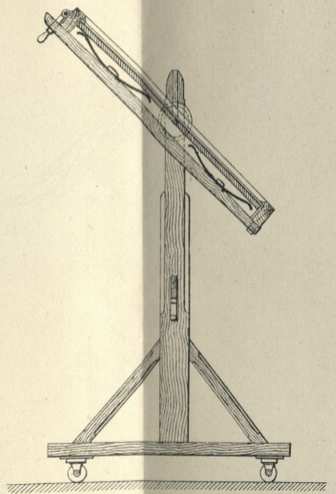


FIG. 2.—SIDE ELEVATION.

FIG. 3.

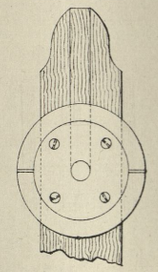
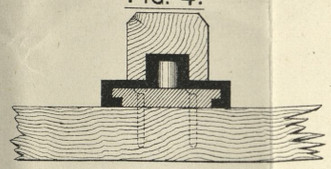


FIG. 4.



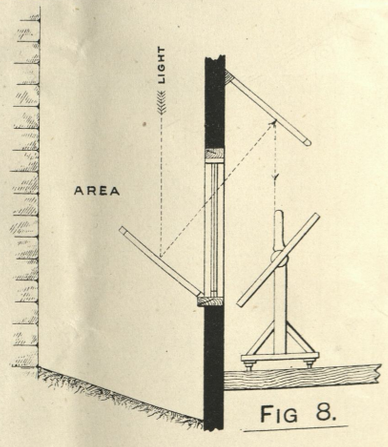


FIG 8.

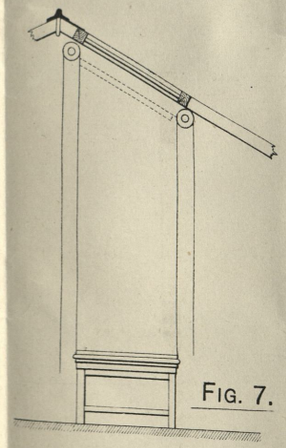
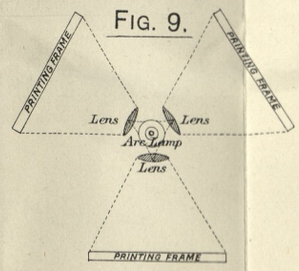


FIG. 7.

FIG. 9.



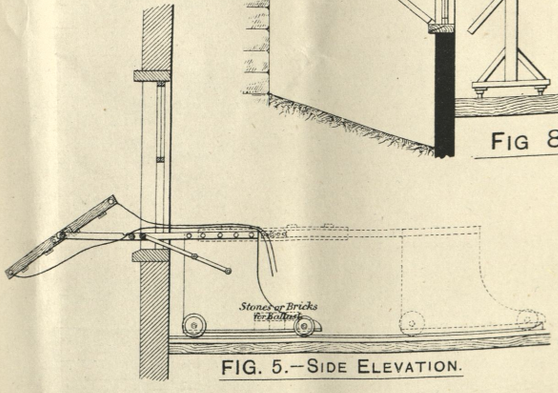


FIG. 5.—SIDE ELEVATION.

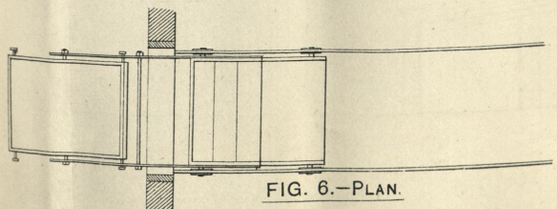


FIG. 6.—PLAN.

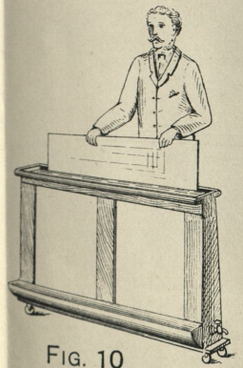


FIG. 10

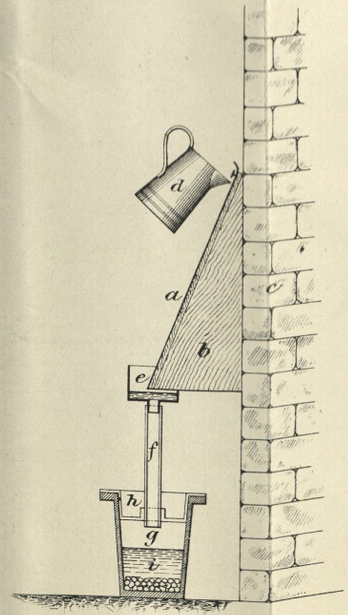
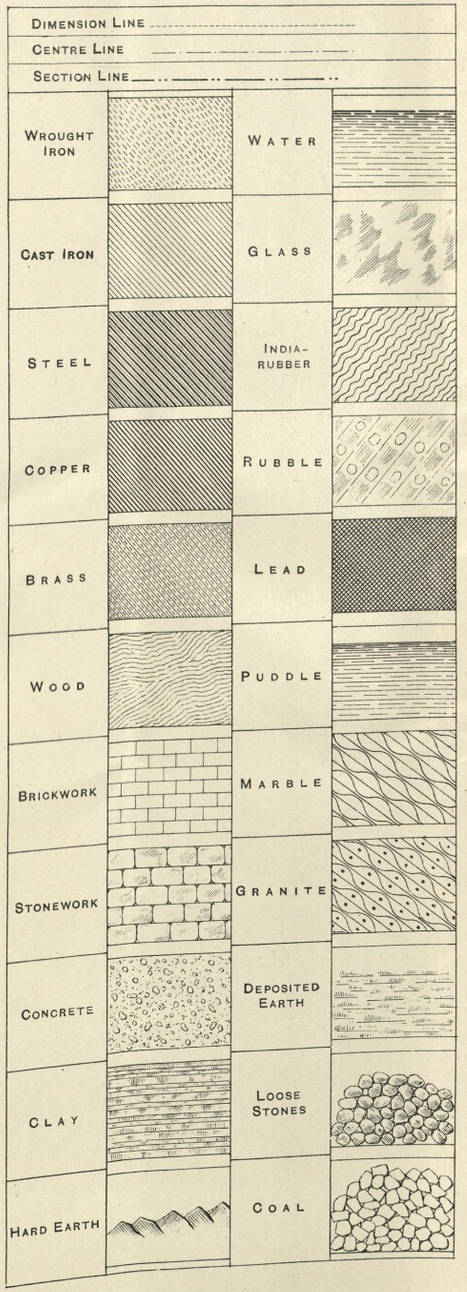


FIG. 11.

FIG. 12.—CHARACTERISTIC HATCHINGS FOR HELIOGRAPHIC PURPOSES.



North of England Institute of Mining & Mechanical Engineers.
Transactions 1894-5.

And.r Reid & Comp.y Ltd. Newcastle on Tyne

To illustrate Mr. B. H. Thwaite's Paper on

"Engineering Heliography," etc.

FIG. 13.—White-lines on Blue-ground (Ferro-prussiate) Process.

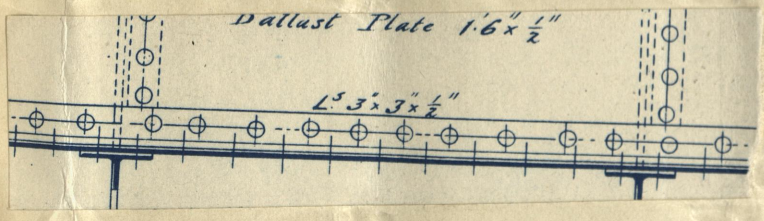


FIG. 14.—Blue-lines on White-ground (Ferro-cyanide or Pellet) Process.

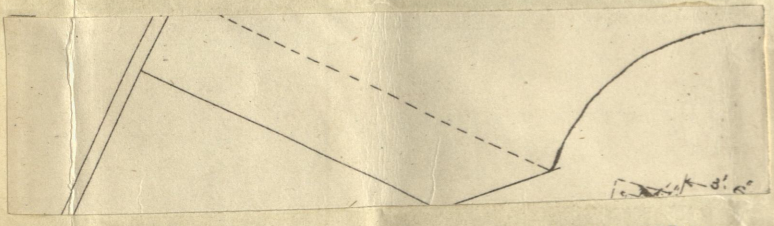


FIG. 15.—Black-lines on White-ground (Ferro-gallic or Shawcross acid-development) Process.

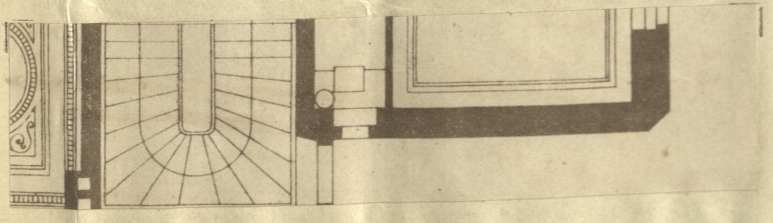


FIG. 16.—Black-lines on White-ground (Ferro-gallic, water-developer) Process.

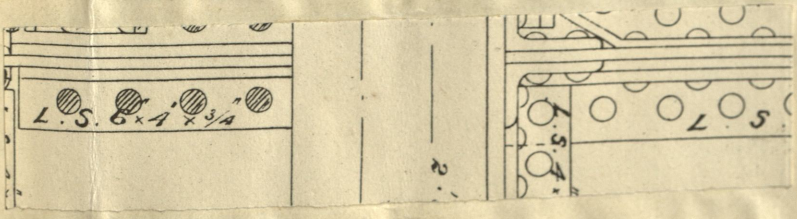


FIG. 17.—Black-lines on White-ground (C.N.) Process.